

Benthic Organisms State of Regeneration Two Years after Carbaryl Application In Willapa Bay

Scott Mazzone BAS Environmental Studies and Science
Michael V. McNamara BA Environmental Studies and Science

Abstract:

In the past 20 years the pesticide, Carbaryl, has been used to control ghost and mud shrimp (*Callinassa californiensis*, *Upogebia pugettensis*) populations in oyster beds of Willapa Bay. This pesticide causes mortality in target as well as non-target species. It is believed that Carbaryl has a short-term effect, and that species will regenerate within 6 months of application. Over the past 10 years, local observation has been that of a decline in the estuary productivity. A census survey of benthic organisms revealed 2 years after last application the area has not returned to its natural state of productivity.

Introduction:

The Willapa Bay oyster beds have long been used commercially as well as locally. These oyster beds have been threatened by burrowing and feeding activities of the ghost and mud shrimp (*Callinassa californiensis*, *Upogebia pugettensis*). These burrowing techniques cause the re-suspension of sediment into the water column. This sediment buries oysters and clogs their filtration functions, causing mortality and a decrease in yields. In order to control the shrimp populations, Carbaryl was introduced as a pesticide in 1963 (Westley 1970). It came into widespread use in the early eighties due to the influx of shrimp populations, and is still the predominant method for the commercial oyster beds of Willapa Bay (Dewitt 1997).

Carbaryl adversely affects all taxonomic groups in varying degrees. It does cause the mortality of the target species, but also to “plants, invertebrates, finfish, birds, mammals, as well as the food webs and even humans” (Hurlburt 1985). Previous research has centered on Dungeness Crab mortalities and the persistence of Carbaryl in water and sediment. The results indicate Carbaryl dissipates quickly in marine environments (within 1 to 3 months), and non-target eradicated species will repopulate sprayed areas from the surrounding region (within 4 to 6 months) (Westley 1970).

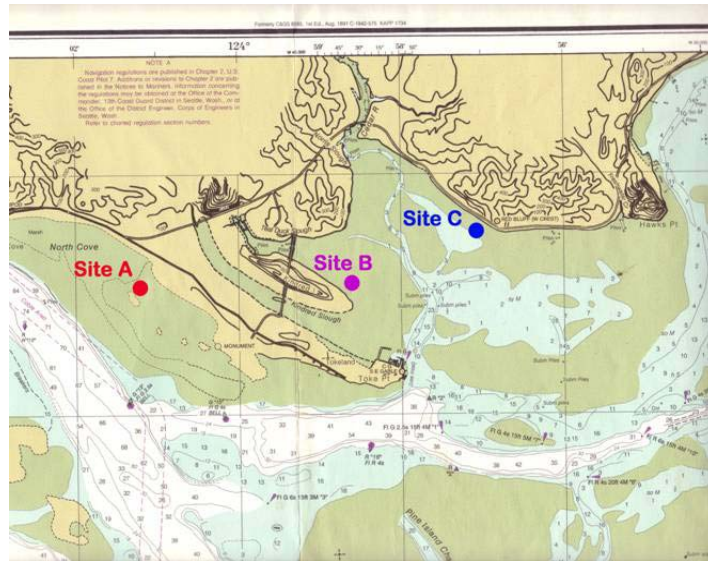
Chemical analysis of water and sediment after application confirms the pesticide's high rate of dissipation to acceptable levels by EPA standards. No research to date has been conducted on the repopulation of eradicated benthic species in a sprayed region.

Lug Worms (*Abarenicda pacifica*) are an indicator species providing insight into the health of an aquatic ecosystem. They are an essential food source for higher trophic species. Lug Worms play a pivotal role in the natural Carbon cycling in marine systems. Their foraging activity oxidizes the sediment providing habitat for other benthic organisms. A large population size would support a productive environment.

The goal of the research is to define if there are any statistical differences between regeneration of species in sprayed sites and the productivity of species in unsprayed sites. Conducting a census of species diversity and populations of benthic organisms, focusing on Lug Worms as an indicator species, will aid in accessing the long-term effects of Carbaryl. The last application of Carbaryl was 2 years ago. The sprayed region should have regenerated to natural productivity well within this time period if current theories are accurate.

Materials and Methods:

The study area is located on the Tokeland Peninsula. The control site (site A) is located in the Shoalwater Bay Indian Reservation mud flats on the west side of the peninsula. The area has been protected since 1992 from the use of Carbaryl. The sprayed sites (site B and C) are located on the East side of the peninsula (see site map).



Site map showing research areas

They are occupied by commercial oyster beds and contain a public shellfish harvesting area. The sites were chosen after establishing site similarities. Ten measurements of water temperature and salinity were obtained from each site, a two-tailed t-test assuming unequal variance with a critical P-value of 0.05 interpreted the results. The data showed similar conditions between sites (temp $P=0.244$, salinity $P=0.201$). Fresh water inputs, currents, winds, and sediment composition were also noted, and found similar between sites.

Three water samples and three sediment samples were acquired at each site and brought to The Shoalwater Bay Environmental Lab for chemical analysis. No Carbaryl was detected at any site, and the chemical composition of water and sediment between sites was consistent.

A 25m X 25m square area, with grid lines at 0.5 m intervals, was outlined over each site. Twenty random sample points were obtained at site A. There were 10 sample points taken for both site B and C, which combined for twenty sample points in sprayed areas. At each sample point, a 0.5m sq area was excavated to a depth of 20cm. All benthic organisms were identified and counted at each point. Burrow openings were also counted at each sample point to determine the relationship between burrow openings and organisms present. Findings were recorded for statistical data analysis. Total numbers of species present, and their population's sizes were compiled for each site and compared. In order to account for the

number of different species (species richness), and the number of individuals of each species (abundance), the Shannon-Wiener Index and the Species Evenness Index were utilized to confirm results. A two-tailed T-test assuming equal variance was run on the index data with a critical P value set at 0.05.

While conducting the research, a difference in the depth of the anoxic layer was noted at each site. As previously stated, the service the Lugworm (*Abarenicda pacifica*) provides in the oxygenated quality of the sediment is beneficial to the health of the estuary. Ten measurements for the depth of the anoxic layer were taken at the sites, and recorded. A two-tailed T-test assuming equal variance was run on the data with a critical P value set at 0.05.

Results:

The control site (site A) was at a natural state of productivity. The benthic organisms were observed as having high levels of biodiversity and population. Evidence of generational succession existed within the control site. The indicator species showed a sustainable level of productivity, while Littleneck clams (*Protothaca staminea*) and Orange Nemertean (*Tubulanus polymorphus*) were the dominant species (See Figure 1).

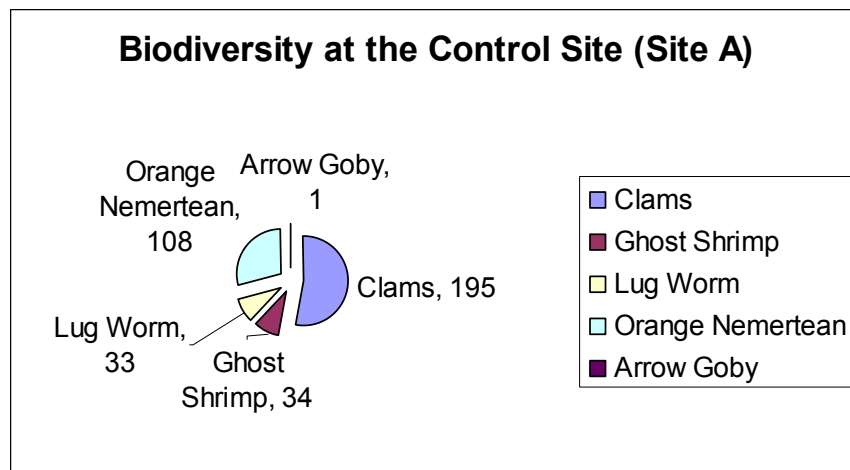


Figure 1. showing the number of species counted.

Both site B and site C contained similar biodiversity to that of site A. The specific species populations were significantly lower (see figure 2), with no evidence of generational succession. The

indicator species showed a non-sustainable level of production. Orange Nemerteans were the dominant species.

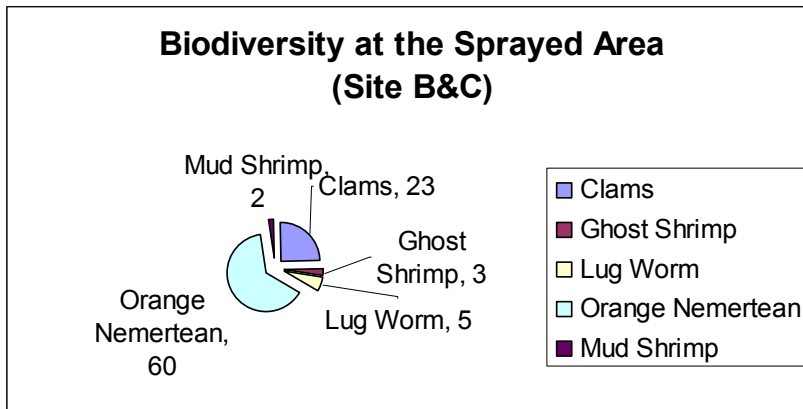


Figure 2. shows the number of species counted.

Comparing the sprayed sites and the control site, there was an obvious species population differences. Species found at the control site were consistently more abundant than that of the sprayed site (see figure 3), and there does not appear to be any indication that burrow openings reflect the amount of organisms found at each sample point. The numbers of species were averaged within the sprayed areas and the control. These results were also compared and are shown in the graph below (see figure 4).

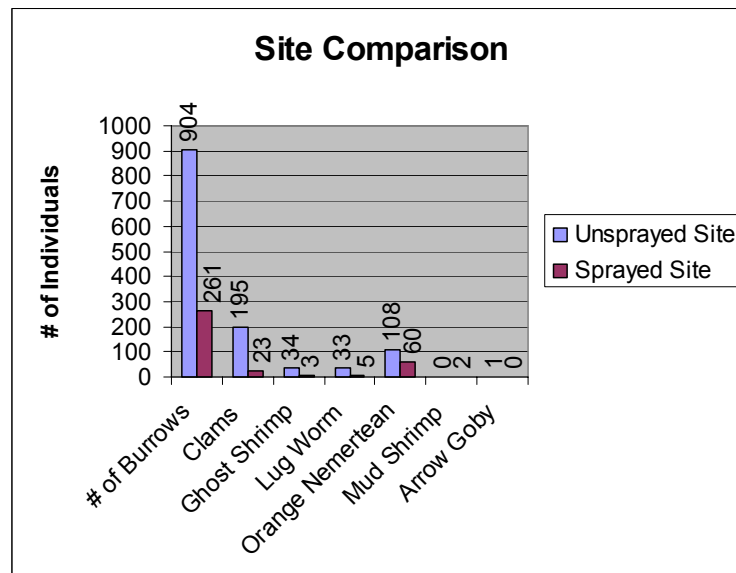


Figure 3. shows comparison of species' numbers between sites.

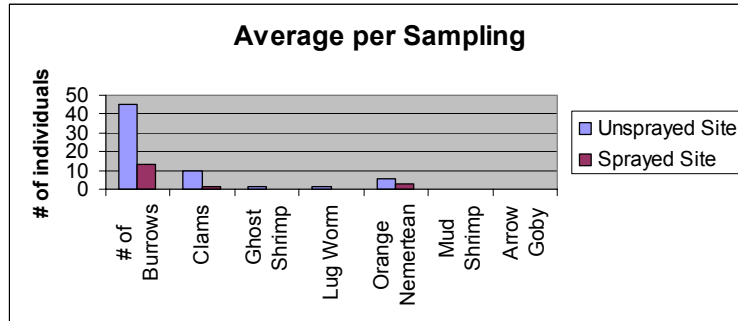


Figure 4. shows average species found per sampling between sites.

Findings were entered into the Shannon-Wiener Index. The results were statistically significant ($P=2.002E-07$). This graph illustrates the difference of species abundance between sites (see figure 5).

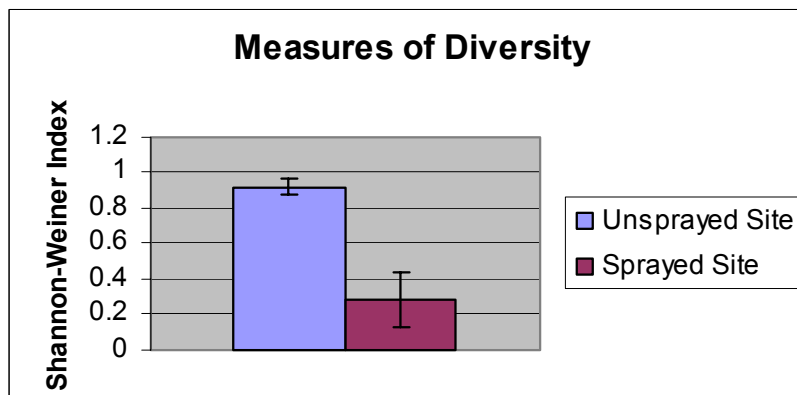


Figure 5. shows species richness between sites.

The data was also entered into the Species Evenness Index. The sites were found not to be evenly distributed. . The index showed a statistical difference ($P=0.00001$) (see figure 6).



Figure 6. shows diversity relative to the maximum possible diversity if all species were represented equally. Therefore, it measures how evenly species are distributed numerically between sites.

Statistical analysis on the depth of the anoxic layer coincided with Lug Worm population densities at each site. The difference in depth between sites was significant ($P=2.455E-15$). (See figure 7)

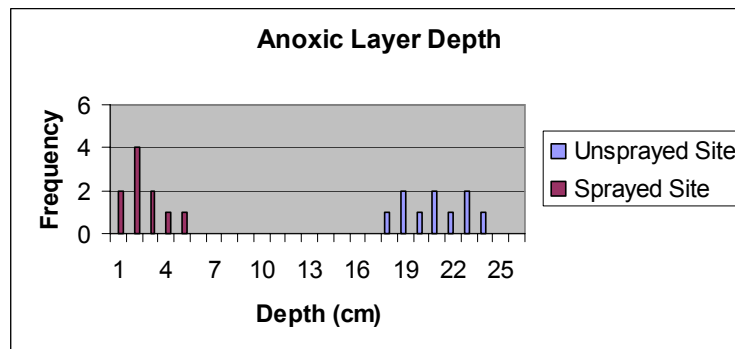


Figure 7. shows the frequency that the depth of the anoxic layer occurred between sites.

The original hypothesis stated that there would be no statistically significant difference in species diversity and population densities at a sprayed site verses a control site. This was based on Carbaryl's quick rate of dissipation, and the theory of eradicated species' ability to repopulate applied areas within an acceptable period of time. The results negate this hypothesis.

Discussion:

In the area of Tokeland, Washington, where this study was implemented, the results reflect and support the ongoing observations of the local community. The results show that the rate of regeneration of the areas that have been treated, does not support the current belief that regeneration of the affected organisms are approaching natural levels of productivity. As this area is within the boundaries of the currently considered application zones, organisms within the system will be further impacted adversely. If the results of this study are concurrent with other treated areas, the relatively low populations of the organisms again exposed to Carbaryl will be exhausted throughout Willapa Bay.

Willapa bay is utilized during the warm seasons as nursery grounds for a wide range of marine organisms from Salmon to Dungeness Crabs and, in addition, a wide variety of migratory birds use the vast mud flats and surrounding area for feeding and nesting. The recruitment times are concurrent with application periods. It would be reasonable to assume that exposure to Carbaryl at these times, would have deleterious implications well beyond current beliefs.

The results differ from the hypothesis on the grounds that eradicated organisms require more time to regenerate than the current theory of four to six months. Even two years after the last application of Carbaryl, the organisms are still in the first stage of attempting to rehabilitate the region. Further research is needed to confirm these findings throughout Willapa Bay, and if results reflect a larger area, present policy regarding the use of Carbaryl should be re-assessed.

Works Cited:

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